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Meeting Report  
1955/24

**REPORT OF THE  
FIFTH MEETING OF THE  
WORKING PARTY ON FERTILIZERS  
OF THE  
INTERNATIONAL RICE COMMISSION**



Held in Penang, Malaya,  
5 - 11 December 1955

Food and Agriculture Organization of the United Nations  
Rome, Italy

January 1956



Beginning in January 1955, reports of FAO Meetings held as part of the Program of Work of the Agriculture Division are being issued in the present form. Reports are numbered chronologically within each calendar year.

Earlier reports of meetings of the Working Party on Fertilizers have been issued as follows:

First Meeting	(Development Paper No. 11)	Bogor, Indonesia	14-19 April 1951
Second Meeting	(Development Paper No. 37)	Bandung, Indonesia	5-10 May 1952
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## INTRODUCTION

The Fifth Meeting of the Working Party on Fertilizers, convened by the Food and Agriculture Organization of the United Nations and held by invitation of the Government of the Federation of Malaya at Penang on 5 - 11 December, 1955, was attended by 27 participants representing 12 governments.

## SUMMARY OF RECOMMENDATIONS

In addition to the recommendations concerned with particular phases of research which are dealt with in the appropriate sections of this report, the Working Party on Fertilizers recommended that:

1. In view of the undoubted value to participants of the Second International Training Course on Soil Fertility in Relation to Rice Growing which was held at Himayatsagar Agricultural Experiment Station, Hyderabad, India, in 1955, consideration should be given to repeating this course as soon as convenient.
2. Copies of the lectures delivered at all the Training Centres on Soil Fertility should be reproduced and circulated to all member countries.
3. Since it is the general opinion that rotation of paddy with dry land crops benefit rice production, Member Countries should continue or even expand investigations on the effect of such systems of agriculture on the growth and yield of rice. It was recognised, however, that one-year rotations continue to be the system best adapted to tropical countries. It was further recommended that great care should be taken in the choice of layout for such long term trials and that agronomists should consult statisticians early in the planning stage to ensure that such trials would yield the maximum amount of information.
4. In view of the value of graphic presentation of data from fertilizer trials to Member Countries, this method should be adopted in future reports. It was further recommended that, where possible, the following data should be recorded for each response curve:
  - (a) An estimate of the area to which the data are applicable.
  - (b) Whether the crop is seeded or transplanted.
  - (c) Whether the area is rainfed or irrigated.
  - (d) As full a description as possible of the soil type or soil series to which the response data refer.

- (e) Time and method of application of fertilizers.
  - (f) Any other relevant information.
5. Member Countries should endeavour to carry out the analysis of soil samples collected from the sites of fertilizer experiments and to give a full description of the soil type or profile in order to study the correlation of yields with data obtained from such soil studies. In making this recommendation, the Working Party recognises that each Member Country will continue to use its proven methods of soil analysis.
  6. Member Countries should give top priority to the study of soil fertility factors in order to make the best use of the high yielding varieties of padi which are at present available. In this connection, it is emphasized that the higher the yield of padi varieties in any particular area, the greater is the need for maintenance and improvement of soil fertility.
  7. In view of the proven value of conducting simple fertilizer experiments on cultivators fields, Member Countries should consider the adoption of this method, of combining sound agronomic research with effective extension. It was further recommended that the principle of random sampling in the selection of sites should be followed.
  8. The attention of Member Countries be drawn to the value of foliar analysis in the study of rice nutrition.
  9. The attention of Member Countries be drawn to the possibility of obtaining technical assistance from FAO in the fields of soils and statistics.
  10. One particular field of rice agronomy should be selected for comprehensive review and discussion at each meeting of the Working Party namely:
    - i) in 1956, a summary of the results from manurial trials, with all forms of NPK, which have been carried out during the last ten years, and
    - ii) in 1957, a study of the effect of nursery manuring on the growth and yield of rice.
- At the joint session of the Working Parties on Fertilizers and on Rice Breeding it was recommended that:
11. When the ad hoc Working Party on rice soil-water-plant relationships presents its report at the 1956 International Rice Commission meeting, consideration should be given to the initiation of research by Member Countries on a co-operative basis.

12. Member Countries shculd continue their investigations on physiological diseases of rice on a co-operative basis.
13. Member Countries should continue co-operative investigations on the interaction of fertilizer response with varieties. It was further recommended that, where such an interaction has already been clearly demonstrated, consideration should be given to separating the effects of the different nutrient elements by suitable investigations and that the time of application of each of these nutrients should be studied in relation to their effect on this interaction. At a later stage in these investigations a study might be made of the gradient of the response curves of different varieties as suggested by the co-ordinator.

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OFFICERS OF THE MEETING

U Hla On of Burma was unanimously elected chairman of the Meeting and V. Ignatieff of FAO Staff served as Technical Secretary.

A Drafting Committee, under the chairmanship of E.F. Allen was elected, consisting of E.F. Allen (United Kingdom), E.P. Baltazar (the Philippines) and I.G. Kapp (United States of America).

ACKNOWLEDGEMENTS

The Working Party expressed its appreciation of the welcome extended to participants in the Meeting by the Hon'ble the Resident Commissioner of Penang; Mr. R.P. Bingham, and the Hon'ble Che Mohd. Khir bin Johari, Assistant Minister for Economic Affairs, who read a message from the Hon'ble the Minister for Agriculture, Federation of Malaya, Enche Abdul Aziz bin Ishak. Appreciation was also expressed to the Government of the Federation of Malaya for the excellent arrangements made for the Meeting and for the demonstrations and exhibits on fertilizers and related agricultural activities in Malaya, as well as the cordial reception and hospitality extended to the participants.

### SUMMARY OF DISCUSSIONS

#### Report on the Second FAO International Training Centre on Soil Fertility

On the recommendation of the Third Meeting of the Working Party on Fertilizers, the Second International Training Centre on Soil Fertility conducted by the Food and Agriculture Organization in co-operation with the Government of India for members of International Rice Commission in or having territories in Asia and the Mediterranean, Near East and Far East areas was held from 18th July to 15th October 1955 at the Himayatsagar Agricultural Research Station, Hyderabad, India. The report on this Centre was presented by the Technical Secretary. The course, consisting of approximately 120 lectures, 40 practical exercises and field demonstrations and a number of excursions to examine the soils and rice culture, was designed to supplement the training of the younger officers responsible for the execution of soil fertility investigations in relation to rice growing in their countries. The teaching staff consisted of 23 lecturers who came from Ceylon, India, Indonesia, Japan and the United States of America. Sixteen of these were provided by India. The reason for the comparatively large staff was that it was felt better results would be achieved if each lecturer covered only subjects in his own particular field and it was very fortunate that the services of outstanding persons could be obtained. Certain administrative difficulties were experienced in arranging a well balanced timetable due to the large number of lecturers from different parts of the world, with a limited amount of time, who had to be fitted in, but these were overcome and the Centre operated very smoothly.

In all there were 32 participants from twelve countries, which compares very favourably with the representation of nineteen participants from seven countries in the case of the First Training Centre held in Coimbatore in 1952.

To the Second Training Centre, Egypt, Federation of Malaya, Netherlands, Thailand each sent one participant; Australia, Indonesia, Iran, Laos, Viet Nam two each; Ceylon and Philippines three each and India sent 12.

Although the Course was presented in English, interpretation was provided for the French speaking participants.

The training provided in Himayatsagar was similar to that given in Coimbatore and centered on discussions of the nutrient requirements of paddy, fertilizer response and practice, soil analysis and diagnostic techniques and the design and analysis of field plot experiments, but some improvements were attempted in light of experience gained in Coimbatore.

An outline of the course was sent to all the lecturers so that each one of them knew what was being covered by the entire course. This assisted them in preparing a more integrated set of lectures. A number of new topics were also introduced such as:

- (a) Photoperiodic response in rice.
- (b) Variety and fertilizer interaction.
- (c) Visual deficiency symptoms.
- (d) Physiology and growth of rice plants.
- (e) Acid and base holding mechanism in the soil including quantitative laws of base exchange and the positive and negative ionic interactions in plant nutrient uptake.

The Working Party expressed much satisfaction with greater interest displayed by Member Countries in the soil fertility, training as reflected in the greatly increased attendance at the Second Training Centre. The Working Party was also pleased to note the improvements that were made in the course and the fact that it was possible to obtain the services of such a large number of outstanding lecturers. However, the Working Party, in considering the outline of the course, felt that there should be a larger number of laboratory exercises and field practicals with a corresponding reduction in lecture periods. Many of the delegates also felt that the lectures delivered should be more widely known and recommended that these lectures should be reproduced in mimeographed form and circulated to the member countries.

Reports from delegates indicated that the Second Training Centre had been greatly appreciated by Member Countries and the training provided had very significantly increased the knowledge and usefulness of those who attended. The Working Party therefore unanimously and strongly supported the suggestion that additional Training Centres were vitally needed to increase the number of adequately trained soil fertility specialists for the programmes of their countries, and recommended that FAO explore with Member Countries the possibilities of holding another such Training Centre as soon as convenient.

The Working Party also took the opportunity to express its deep appreciation to the Government of India for its contribution to the two Training Centres on soil fertility.

The effect of Crop rotation on the Growth  
and Yield of Paddy

In discussing crop rotations with paddy, a distinction has to be made between temperate regions and the tropics. In the former, the use of rotations is the common practice as, for instance, in Australia, Italy and United States of America. In the latter paddy is grown at least once each year and this is also the case in Japan.

In the tropics one must also distinguish between dry and wet paddy. The dry paddy may be rotated with other dryland crops if water supply is adequate. Whether wet paddy is rotated during off-season with any other crop depends largely on the water supply and nature of the soil. On poorly drained land a second crop of wet paddy is taken as nothing else will grow.

On well drained land, if there is sufficient water, a dryland crop is planted especially after an early variety of paddy. In some places with favourable soil structure and texture, even if there is only limited water supply, some crop may be grown making use of soil moisture remaining after the paddy crop. On the other hand, in some areas where the soils are very heavy textured and bake hard on drying, it is not possible to grow a dryland crop during the off-season.

Japan, perhaps, can be presented as a special case in that it is a country with a temperate climate and yet grows paddy every year. During the off-season, on well-drained and fairly well-drained soils, some dryland crop is grown, but poorly drained land is left fallow.

In the tropics one of the specific characteristics of wet paddy culture is the possibility of continuous paddy cropping without substantial decrease in the fairly low yields and little use is made of manures and fertilizers. On the other hand, monocultures with dryland crops, including dry paddy, generally result in rapid decrease of crop yields.

It is not clear which crops are most suitable for off-season cropping where this is practiced. Legumes grown for pulse generally do not appear to increase the yield of paddy; legumes grown as green manure benefit paddy, although it is difficult in some areas to introduce such a crop into the rotation.

There is little experimental evidence in the tropics to show that rotations with paddy in which the intervals exceed a year have any influence. However, in Japan, where paddy cultivation methods do not differ very much from those of tropical countries, some experiments indicated that better yields of paddy can be expected with longer rotations, especially when fertilizer is used. In the humid tropics, however, the choice of the alternative crop is difficult because of poor water control and drainage.

In the United States, Australia, Italy and other countries where wet paddy is grown in a different manner from tropical areas, longer rotations are necessary to maintain good paddy yields. In these countries, fertilizers are generally used. In its requirements, the paddy grown in these countries corresponds in many respects with upland paddy in tropical areas, which also cannot be grown continuously. Although there is not much information about the rotation of paddy with other crops in one-year rotations, it is the general opinion that alternation with dry fallow or dry-land crops will benefit paddy production. It can be assumed that with thorough drying, the soil will change its physical, chemical and micro-biological properties.

It is possible that regular use of fertilizers with paddy may improve conditions for other crops. Experience with crops such as wheat, potatoes, etc. has shown that the increased use of fertilizers reduces the need for strict rotations. The general practice of longer rotations in some countries, especially in the temperate regions, is not only due to favourable conditions which allow more variation in the choice of crops, but also because livestock is carried on the farms. The small size of tropical farms is not conducive to long rotations.

In Australia the rotation most widely used in New South Wales is: Paddy pasture. A mixture of Trifolium subterraneum and Lolium rigidum is sown in the rice stubble. For two years or more, pastures are dressed with 125 kg. superphosphate per hectare per annum but the paddy crop is not fertilized. The increasing adoption of the pasture phase was assisted by the rising value of sheep. An experiment with five different 5-year rotations, including fertilizer treatments expected to run a 25-year course, is at present being conducted.

Natural regeneration (after paddy), wheat, grazing oats, pasture and pasture sown in the paddy stubble, are the alternatives in the rotations. The amounts of fertilizers used in the different rotations are determined by the requirements.

In British Guiana no systematic crop rotation is practised. Paddy follows paddy and two crops per annum are often planted, yielding 5000-5600 kg. per hectare. Periodical flooding of the fallow land has proved to be a good measure for improving soil conditions. Green manuring with Vigna repens increases the yield of paddy.

In Lower Burma it is difficult to practise any rotation with paddy but in some parts of Burma this is feasible, and sugarcane, bananas and other crops are grown in rotation with paddy. Improvement in irrigation facilities would greatly increase the possibility of practising rotation with paddy.

In Egypt the two rotations generally practised are wheat - maize - clover - paddy - wheat or wheat - paddy - wheat. A number of experiments showed that the yield of paddy was much better after legumes, than after non-legumes, and there was considerable response of paddy to phosphate in both cases. However, in the case of paddy not preceded by legumes the low control yields gave a high percentage increase due to application of phosphate.

In Fiji three experiments involving paddy rotation have been started. The alternate crops were green manure, maize, cassava, sugar cane, sweet potatoes and ley (Brachiaria mutica and Ischaemum aristatum). No conclusive data are as yet available.

In French Tropical Africa rotation experiments are being conducted with the objectives of replacing shifting cultivation and of combining a subsistence crop with a cash crop while preserving soil fertility in the newly opened up region.

In Cassamance (Senegal) a semi mechanized rotation is being tested which consists of:

First year	-	Millet as green manure ploughed under before the end of the rainy season.
Second year	-	Groundnut.
Third year	-	Dry paddy.
Fourth year	-	Groundnut.

In French Sudan a rotation of irrigated rice with cotton is being attempted in several places.

In middle Congo in the valley of Niari where there are two rainy seasons, a rotation of groundnut, upland paddy and a green manure crop grown during the dry season, is being tried for the last two years. The green manure crop is ploughed under at the beginning of the rainy season.

In India, rotations are not generally followed in wet paddy culture, but legumes are grown as catch crops depending on the availability of moisture. As the lowlands are submerged for 6 - 8 months, growing of dryland crops in the rotation is not possible. In dry paddy areas in the north of India, and where cultivation is not possible, gram or peas are grown as catch crops, Khesari or red gram are broadcast, while there is moisture in the field. In the south, black gram, green gram, horse gram etc. are grown. Under irrigated conditions, paddy - berseem is grown in north India and on lighter soils paddy - potato or vegetables may be grown. In the east of India, rice - jute is the main rotation, while in the south double cropping of rice is usually practised, though groundnuts or cotton may also be grown. Sugar cane may be grown with paddy once in 3 to 4 years. Green manuring with Crotalaria juncea (sunnhemp) and Sesbania aculeata (Dhaincha) has proved to be very profitable for paddy.

In Indonesia, because of the small size of the holdings it is essential to grow paddy every year, which is the staple food of the farmer. Where sufficient irrigation facilities are available a rotation of wet season paddy - dry season paddy - soybeans - wet season paddy may be followed, but with less favourable water supply a system of wet season paddy - soybeans or peanuts - maize has to be followed.

In an experiment during the dry season on the rotation of wet paddy with sweet potatoes and with peanuts, no significant difference between those crops was observed. When Crotalaria anagyroides and Crotalaria juncea were used as green manure and included in the rotation, the yield of the subsequent wet paddy crop was increased significantly. Another experiment with fallow maize, maize plus C. juncea and C. juncea alone showed a slight but significant increase in the yield of the subsequent paddy crop as a result of the rotation with maize plus C. juncea. The conclusions, drawn from six rotational experiments, including sugar cane, are as follows:

1. The yields of the wet paddy crop following sugar cane were lower than after other dryland crops.
2. In a paddy-sugarcane rotation which included maize as an intervening crop, the poor results obtained - despite the large dosage of ammonium sulphate applied to the sugar cane may be attributed to the great absorption of plant nutrients by the maize crop.
3. The yields of the main paddy crop following the off-season paddy crop were even lower than after sugar cane.
4. The effect of phosphate and ammonium sulphate on paddy was, in general, good. However, phosphates tended to depress the yield when their application advanced the flowering time of paddy, because of severe stemborer damage.
5. Manuring of the late planted paddy decreased mentek disease.
6. On fertile soils, rice yields were almost the same whether preceded by sugar cane or other upland crops.

Fertilizers in Indonesia are usually applied to the paddy crop and not to the dryland crops, with the exception of commercial crops such as sugar cane, tobacco and vegetables. The residual effect of ammonium sulphate applied to sugar cane and tobacco is generally negligible, whereas phosphates and green manures have a residual effect.

In Italy, there are three systems of paddy culture: the permanent paddy lands; the semi-permanent paddy lands; and paddy in a long rotation with other crops.

The permanent rice culture is practised on a comparatively small area which comprises only about two to three percent of the total rice acreage. This system is in use on poorly drained lands and the yields are somewhat inferior to those obtained under the system of long rotation even with the use of larger quantities of fertilizer.

In the semi-permanent system, once every 10-12 years, a dry cultivated crop follows for one or two years. The dryland crops are wheat, pasture or oats.

In the third system, the rotations are of three, four and five years' duration. Wheat and pasture are the main alternating crops. Fertilizers and manures equivalent to 100 kg. N, 100 kg. P<sub>2</sub>O<sub>5</sub> and 110 kg. K<sub>2</sub>O are used. Green manuring with clovers and grasses is also customary.

In Japan there are three groups of rotations. In the first, wheat or barley or rape are grown in the winter and receive 60 kg. each of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O per hectare. In the warm south-west regions, soybeans are occasionally grown between the rows. This rotation is found in well-drained paddy lands. In the second, Astragalus sinicus, which is tolerant of wet soils, is also planted during winter. This crop is not fertilized and is used as green manure. In the third, the land is winter fallowed. Double cropping and applications of fertilizer are most effective in the well-drained soils. Since 1945, experiments have been conducted on rotations in which rice is not grown every summer. The results of these experiments indicate that higher yields of rice may be achieved by a longer rotation.

In Malaya rice is not generally rotated with other crops because wet paddy cultivation is virtually confined to alluvial clay soils, and many of these dry out very hard in the off-season, while others remain swampy and support a vigorous off-season growth of sedges and other aquatic plants. There are, however, certain favoured localities where regular rotations with paddy and other crops are possible, and some experimental work has been conducted with these.

Previously paddy was followed by fallow which usually ran to grasses and swamp vegetation. In a new drainage area on the West Coast, maize is being grown in rotation with paddy but the area is limited because only green cobs can be sold. There is also some interest in soyabean and tobacco but the area is limited by soil type and rainfall. It is difficult to establish green manure crops, though Sesbania aculeata has grown well in two experiments out of five.

Off-season cultivation with dry-land crops is limited in area in Malaya by climatic, soil and economic factors, but where carried out it usually leads to increased yields from the subsequent wet paddy crop, and manuring sometimes enhances these yields. The successful rotation of paddy with other crops facilitates weed control. Injudicious cultivation of paddy land carried out when soil conditions are unsuitable may reduce paddy yields as a result of damage to soil structure. Similar harmful effects may also result from excessively deep cultivation. There is no indication that the practice of green manuring is likely to become established in Malaya except insofar as the natural weed growth in the off-season is sufficiently dense to be considered a green manure.

In Mexico sweet clover is often grown after wet paddy and once established, sufficient seed is allowed to mature in subsequent years to ensure a good volunteer growth. Such a rotational practice is found very profitable, because sweet clover not only provides food for livestock but greatly improves the yields of paddy.

In Pakistan long-term rotations are not practicable, although some results are claimed with berseem clover (Trifolium alexandrinum) on alkaline soils. In Kalar, a paddy-wheat rotation is practised. Wheat definitely depresses the yield of paddy unless manure or fertilizer is added. In Sind province, it was found that it is more profitable to grow a legume after paddy than to fallow the land.

In Sarawak there is often a dry fallow period between the paddy crops. On less intensively cultivated wet paddy land, where water control is not efficient, a bush fallow interval of three to four years usually occurs between the successive crops.

In the United States of America, generally the yield of wet paddy declines, if grown year after year, hence, in order to increase the organic matter and suppress weeds, paddy is grown in rotation with a variety of other crops in different States. Where drainage is good, small grains and forage legumes are grown in a paddy rotation of several years duration. In the Gulf Coast paddy areas, small grain crops are used for pasture and green manure. Sturgis found that the yield of paddy on deflocculated Crowley silt loam soil was not increased by applications of 670 kg. per hectare of 8-8-8 fertilizer unless organic matter was added to improve the soil structure. Long and continuous irrigated paddy culture resulted in: deflocculated colloids; increase of pH from 6.0 to 7.1; accumulation of colloidal iron and silica; reduced nitrogen content of the soil; decrease in readily available phosphates and exchangeable potassium. The ploughing under of legumes was the most effective treatment for improvement of the physical condition of the soil.

In California, due to the high water table during the irrigation season, it is difficult to grow any crop in rotation, but barley or wheat shows some promise. Pastures are sometimes rotated with rice.

### Designs of Rotation Experiments

The Working Party on Fertilizers noted that, although effective systems of crop rotation were being employed in some of the member countries, in many others the existing practices were based merely on usage and, therefore, there was a definite need for conducting long-term rotation experiments. These studies could include not only crop yields but also the quality of crops and the changes in the chemical, physical and microbiological properties of soils. For studies of the effect of rotations, on crop yields experiments based on modern principles of statistics were advocated. It was felt that there would be two kinds of these experiments, viz:

(a) Simple crop rotation experiment

and

(b) Rotation experiments with fertilizer treatments.

#### Simple crop rotation experiments

The Working Party realised that annual rotation in paddy cultivation was generally not employed in South East Asia, and it, therefore, considered only the case of within year rotation where paddy is grown in the main season and a secondary crop, such as maize, soybean, berseem etc. is grown in the off-season.

#### Case I - Effects of various off-season crops

Treatments were illustrated as shown below:

	1	2	3	4	5	
1st year main crop	P	P	P	P	P	P - Paddy
Secondary crop	M	C	G	P	-	M - Maize C - <u>Crotalaria juncea</u>
2nd year main crop	P	P	P	P	P	G - Groundnut

The use of Randomized Blocks or Latin Square design was suggested. One of the possible layouts using Latin Square design was as follows:

<u>1st year main season</u>	<u>Off-season</u>	<u>2nd year main season</u>
P P P P P	G P C M -	P P P P P
P P P P P	P G - C M	P P P P P
P P P P P	C M G - P	P P P P P
P P P P P	M - P G C	P P P P P
P P P P P	- C M P G	P P P P P

It was noted that the effect of using different off-season crops would have to be studied by comparing the total value of production over the whole year. The use of the method of covariance, utilizing first year paddy yields, was also considered. In cases where some of the off-season crops were always grown together with certain fertilizer applications, it was recommended that the fertilizer treatments be incorporated along with the crop treatments. It was, however, pointed out that in such an experiment it would not be possible to separate the effects due to crops from those due to fertilizers.

Case II - Use of different off-season crops in different years

These experiments were meant to answer questions such as, should one and the same off-season crops be grown in successive years, or should different off-season crops be grown from year to year. For purposes of illustration the following treatments were considered:

	<u>Treatments</u>			
	1	2	3	4
1st year main crop	P	P	P	P
secondary crop	M	S	M	S
2nd year main crop	P	P	P	P
secondary crop	M	S	S	M
3rd year main crop	P	P	P	P

As before, it was noted that it would be necessary to compare the total value of production over the entire cycle by using appropriate value indicators of different crops.

Rotation experiments with fertilizer treatments

The Working Party in this case considered the problem of optimum allocation of fertilizers between the main crop and off-season crop. Again, for purposes of illustration only, it considered a case where a cultivator has only enough fertilizer for a single application at the rate of 40 kgs. N per hectare throughout his paddy field on which he grows maize as a secondary crop. The type of experimental treatments considered were:

- (i) 40 kgs. N per hectare to paddy and none to maize
- (ii) 30 " " " " " 10 kgs. N per hectare to maize
- (iii) 20 " " " " " 20 kgs. N per hectare to maize
- (iv) Control. No fertilizer to either crop.

An ordinary randomized block design with four plots per block and replicated three times was suggested.

The Working Party then went on to consider a more complex case of determining optimum method of allocating fertilizers together with the use of different off-season crops, e.g. the different off-season crops tried were: (i) maize; (ii) soyabean; (iii) groundnut; (iv) paddy; and (v) land left fallow, and the different ways of allocating fertilizers were as before: (1) 40-0, (2) 30-10, (3) 20-20 and (4) 0-0. It was suggested that a split plot layout as shown below, be employed:

M A I N   S E A S O N

Rep. I

P 20	P 20	P 30	P 30	P 40
P 40	P 40	P 20	P 0	P 20
P 0	P 30	P 0	P 40	P 0
P 30	P 0	P 40	P 20	P 30

Rep. II

P 0	P 40	P 30	P 30	P 20
P 40	P 20	P 20	P 0	P 30
P 20	P 0	P 0	P 20	P 40
P 30	P 30	P 40	P 40	P 0

Rep. III

P 20	P 30	P 0	P 20	P 40
P 40	P 0	P 40	P 0	P 30
P 0	P 40	P 30	P 40	P 20
P 30	P 20	P 20	P 30	P 0

O F F   S E A S O N

G 20	- 20	M 10	P 10	S 0
G 0	- 0	M 20	P 40	S 20
G 40	- 10	M 40	P 0	S 40
G 10	- 40	M 0	P 20	S 10

- 40	S 0	G 10	P 10	M 20
- 0	S 20	G 20	P 40	M 10
- 20	S 40	G 40	P 20	M 0
- 10	S 10	G 0	P 0	M 40

S 20	M 10	- 40	G 20	P 0
S 0	M 40	- 0	G 40	P 10
S 40	M 0	- 10	G 0	P 20
S 10	M 20	- 20	G 10	P 40

P - Paddy

G - Groundnut

M - Maize

S - Soyabean

(Numbers in plots refer to kgs. of Nitrogen per hectare)

	d.f.		d.f.
Replications	2		
Secondary crops	4	Fertilizers within crop treatment (i)	3
Error (a)	8	" " " (ii)	3
Fertilizer treatments	3	" " " (iii)	3
Fertilizer x crops	12	" " " (iv)	3
Error (b)	30	" " " (v)	3
Total	59		

A straightforward analysis, as shown on the left, would provide a valid test for the effects of different secondary crops. Sub-plot analysis would, however, give little useful information, particularly if the fertilizer x crop interaction was significant. Since the importance lies in determining whether the fertilizer treatments differ significantly for each of the crop treatments, a modified form of analysis, as shown on the right, was recommended.

In this connection, it was pointed out that, although some of the treatment comparisons, e.g. fertilizer applied to land left fallow, were of no practical importance, it was nevertheless necessary to have the same sub-plot treatments in each of the different main plots.

The Working Party finally went on to discuss some of the practical considerations concerning the conduct of long-term rotation experiments. As long-term rotation experiments frequently involve large sums of money and require considerable manpower, it was emphasized that particular care be given to the choice of proper experimental design, and that appropriate statistical authorities be consulted from the very beginning. It was pointed out that, since it was of very great importance to avoid the use of variable sites, the possibility of running the experiment as a uniformity trial for the first year be also considered. In this connection, it was explained that a delay of one year in an eight to ten year experimental programme might not be too serious.

Since considerable difficulties are introduced when different crops are grown in adjacent plots, attention was drawn to the necessity of including adequate guard rows and erecting bunds to provide sufficient turning headlands for cultivating different plots at different times. Since adjustments for missing plots are necessarily more difficult in case of long-term experiments, the need for protecting plots from damage by insects, birds or animals was emphasized. It was suggested that Latin Square design be avoided at places where crop damages are known to occur frequently. Unless soil exhaustion and fertilizer crop interaction were under study, it was recommended that sufficient basal manuring be given to all plots to maintain crop yields at a reasonable level.

In conclusion, the necessity of ensuring that each crop in the rotation be sown and harvested at the most suitable time was stressed.

### Responses of Paddy to Fertilizers

In accordance with the recommendation made by the Fourth Meeting of the Working Party on Fertilizers, FAO prepared on basis of data submitted to it by I.R.C member countries, a working document illustrating methods of presenting results of fertilizer trials. A procedure to be followed in case of factorial experiments, involving several levels of N together with several levels of P, was also presented and agreed upon. Member Countries approved the different techniques used in plotting response curves and agreed to prepare, reports for their countries along the same lines for presentation at the next meeting of the Working Party. The Working Party also recommended that where available data permit, optimum doses giving maximum net profit to the cultivator be also shown on appropriate graphs. It was further recommended that, in order to learn about the potential increases in production that can be brought about by the use of fertilizers, at least an estimate be supplied of the area under paddy to which the different results were applicable.

Concerning the presentation of data by regions or states, it was suggested that a far more useful purpose would be served by giving the data according to areas having similar soils. It was further suggested that, where possible, supplementary information such as method of planting, source of water supply, time and method of applying fertilizers etc. be also given.

The delegates described the results of fertilizer experiments in their respective countries, and it appeared that in Malaya at Kota Bahru, on an old flood plain river alluvium, the chief fertilizer requirement is nitrogen, and dressings even in excess of 105 kgs. N per hectare can be expected to give a response. Neither P nor K give a response at Kota Bharu, but the site had received a dressing of phosphatic bat guano four years earlier. The lack of response to P is somewhat surprising, because response to this plant nutrient element has been generally observed in the area. At Teluk Chengai, a station which has received regular triennial dressings of a phosphatic bat guano, nitrogen is the chief fertilizer requirement. Its effect is enhanced in the presence of added phosphate. At Teluk Chengai, a dressing of 15 lb. per acre of K<sub>2</sub>O is beneficial, but a larger dressing either has no effect or may be harmful.

In Malaya, there are over a million acres of peat soils, the greatest proportion of which are found on the West Coast. These soils, which do not normally grow paddy, are now being reclaimed and it is found that burning and fertilization are giving promising results. Paddy yields up to 2000 kgs. per hectare have been obtained. A highly significant response to P is obtained, but no effect of trace elements can be observed.

In the Philippines, it is found that the use of 250 kgs. of a 12-12-0 fertilizer mixture is very profitable on wet paddy and 300 kgs. on dry paddy.

In Madagascar, on alluvial soils, fertilizer trials have been conducted from 1950-1954 with lime, stable manure, green manure and inorganic fertilizers.

Lime was applied in 1950 and again in 1953 and 1954. During the seasons 1950-52, no significant results were obtained, but in 1953 the yields on all the treated plots were superior to those on the control plots. In 1954, all treatments were significantly superior to the control, and the application of slaked lime at 2000 kgs. per hectare or 1000 kgs. of lime plus 25 tons of stable manure gave better results than the application of 10 tons of green manure. It would appear that lime has a good effect on paddy yields, but its action seems to be delayed.

In Madagascar, foliar diagnosis using the flag (uppermost) leaf appears to give a positive correlation with yield and from the analyses of these leaves it is possible to get an idea of the fertilizer requirements of the wet paddy crop.

In Thailand, a number of experiments of different types are being conducted in order to study the effects of N and P at 3 levels each, the effects of N, P, K and Ca, interaction between varieties and fertilizers, spacing trials, time of application of fertilizer trials etc. The profits and losses from different treatments are being calculated, taking into account, amongst other things, the cost of broadcasting fertilizer and harvesting the extra yield. Interesting results are expected when the data for a few years become available.

In Burma, the responses to fertilizers are very low and, therefore, the profits that can be expected from the use of these materials are not promising.

In India, nitrogen gives a universal response with paddy and the organic forms of nitrogen, such as green manure crops, green leaves of Gliricidia maculata etc. have proved to be more effective than chemical nitrogen. Phosphate deficiency has been observed on some soils, as, for instance, the lateritic soils. The need for potash has not yet been generally felt. From the experiments established to study separately the different factors in the Japanese method of paddy cultivation, it was found that fertilizers are responsible for 30 percent of the increase in yield. In some experiments it was found that manuring the nursery with 2.25 kgs. N per hectare transplanted had not much effect on the final yield, and also root pruning before transplanting had no adverse effect. This leads to consideration of the question as to whether it is necessary to avoid root injury during transplanting, as is recommended.

In Korea, on an equal nitrogen basis, soyabean meal has been found to produce a better response than ammonium sulphate, but the ratio of grain weight was increased by the latter.

In Japan, silica gel or furnace slag (containing 30 to 40 percent silica) gives an increase in yield of 10 to 20 bushels per acre, providing there is an adequate supply of N, P, K. There is evidence to show that some soils, especially sandy soils, may be lacking in available silica, which comes into solution in weak acids at a pH4. It is found also that where no response is obtained by the application of silica, either irrigation water or the soil contains much available silica.

Sampling and Analysis of Paddy Soils for  
Fertilizer Requirements

In the United States of America, as elsewhere, considerable deliberation has been given to the perplexing problems associated with sampling and analysis of wet paddy soils to determine profitable fertilizer practices. It is becoming more evident that chemical soil tests conducted under the great precision in sampling and rapid analytical techniques can, at best, serve only as an indication of what response fertilizers or other soil amendments will produce. The extent and/or economic value of that response must be determined by results of large numbers of field fertilizer trials correlated with the soil test data from the untreated test sites.

Although the value of soil testing is limited, it is nevertheless of great importance because the number of fertilizer field trials can be reduced after sufficient initial correlation studies have been completed. Considerable tonnage of fertilizers is wasted on fields which are thought to be deficient in nutrient elements, because of the incorrect assumption that all fields within a given soil type region have identical fertilizer requirements. Conversely, innumerable paddy fields are producing only a fraction of their economic potential, because of the insufficiency of the fertilizer nutrient supply, the necessity for which could be clearly indicated by simple soil tests.

Some major problems to be considered in the use of rapid soil tests on paddy soils include methods of sampling, time of sampling, methods of analysis, correlation of the analyses with field (and greenhouse) tests, and interpretation of the tests in terms of profitable fertilizer use or other soil needs.

Method and Time of Sampling. Sampling of both topsoil (furrow slice) and upper subsoil (15 to 30 cm) is desirable during the initial stages of organizing any large scale testing program, in order to characterize the general nutrient status of the subsoil layer in which a portion of the rice roots may occur. The subsoil sampling may be discontinued after the various soil types are adequately represented, since subsoils usually remain rather constant in chemical composition among different fields within similar soil types, even though the same field topsoils may vary considerably, reflecting past management practices. For topsoil sampling (0-15 cm), limited experimental work in the United States of America has indicated that the average fertility level of individual fields of less than 10 hectares in size may be satisfactorily represented by a composite of a minimum of 15 individual samples from random spots over the field. This minimum still applies, even though the field may be as small as 1 acre or less. Large fields above 10 hectares in size may be represented by a composite of at least 25 individual random samples, and fields over 20 hectares in size should not be sampled as one unit. Numerous tools may be satisfactorily used for sample collection, with usual care to avoid contamination with chemicals or occasional organic deposits on top of or within the mineral soil.

Time of sampling is of greater significance upon results than method of sampling, particularly with respect to submerged paddy soils. Considerable experimental work has indicated the changes in nutrient availability which take place under submergence, and the extent of these changes is influenced by factors including (1) time and system of flooding, which controls the oxygen supply of the water, (2) source and temperature of the flood water, and (3) basic soil factors, such as, amount and type of organic matter, texture, structure, and initial total chemical composition. These variable factors seriously complicate any attempt to evaluate results of chemical tests on soil samples collected and tested in the submerged condition. Thus for advisory purposes it seems desirable to sample rice soils during periods when the fields are not flooded, specifically when the soil is at a moisture content ideal for cultivation without serious puddling or cracking.

At present, methods of analysis are probably the least significant source of error in the evaluation of fertility requirements of paddy soils. Most of the buffered salt solutions currently employed for extraction of exchangeable cations give reproducible results which have indicated satisfactory correlation with paddy response to fertilizers and lime in the limited comparisons available. The use of neutral normal ammonium acetate permits rapid determination of potassium, calcium, sodium and magnesium with a flame spectrophotometer; other active ions including ferrous and ferric iron, manganese, aluminium, sulphate and phosphate may be rapidly determined by colorimetric or turbidimetric procedures on the same extract. Total nitrogen, measured directly by Kjehdahl or approximated from the organic carbon content, serves as a satisfactory approximation of the nitrogen requirement of paddy soils, if interpreted with due consideration to drainage conditions, pH, and other soil factors affecting nitrogen release and utilization. More specific estimates of nitrogen requirement may be gained by incubation and subsequent determination of nitrate and/or ammonium released, but interpretation of such results presents problems similar to those with total nitrogen.

The numerous phosphorus extracting solutions all have advantages for specific forms of soil phosphorus on specific soil types. Extensive uniform phosphorus correlation tests with dryland crops in the United States of America have indicated reliable results with the 0.1 N hydrochloric acid in 0.03 N ammonium fluoride extraction on wide varieties of acid and neutral soils; sodium bicarbonate extractions appear to be more suitable for alkaline soils.

The dichromate-sulphuric acid wet oxidation method for carbon is readily adapted to rapid analyses of large numbers of samples, and provides a useful approximation of readily decomposable organic matter. A measure of organic matter content is essential as an aid in estimation of the extent of reduction under submerged conditions.

Experience in evaluating over 120,000 samples in Arkansas has indicated that the rapid soil tests should include as a minimum a determination of organic matter, pH, exchangeable H, K, Ca, Mg and easily soluble P, to provide a satisfactory basis for evaluation of all major element needs. The base exchange capacity can thus be estimated by summation of the exchangeable H, Ca, Mg and K (and Na in areas where applicable). .

It is emphasized that extreme analytical accuracy is of little significance in evaluating fertilizer needs of soils. Soil scientists cannot interpret the results, nor can cultivators apply the materials needed with the accuracy implied by time-consuming analytical procedures. The methods employed by Arkansas, and other State soil testing services in the United States of America, are designed for a compromise of optimum accuracy with optimum speed, permitting complete processing of at least 600 samples daily. For more fundamental studies on samples from experiment station plots or special problem areas, more complete methods may be employed as used in Japan and Malaya.

#### Interpretation of results for fertilizer recommendations

Experience in testing soils from fields or soil areas of relatively high and low productivity indicate that such results are not sufficiently consistent to serve as a basis for evaluating soil tests. On the other hand, if soil samples are collected from large numbers of experiments on cultivators' fields and compared with the final yield response to different fertilizer treatments, a sufficiently accurate basis can be obtained by which soil test nutrient levels may be established according to low, medium or high expected response to the application of the different nutrients.

It must be emphasized that a classification of the expected degree of response of a given element should be based upon consideration of the complete soil test data, and not simply the soil test level of that given element alone. The activity and availability of any given soil nutrient is influenced by the concentration and activity of other soil nutrients, pH and organic matter content, so that consideration must be given to the balance of measurable fertility factors as a whole under the reduction effects of submergence.

As an example, in Arkansas it has been found that the response of wet paddy to phosphate cannot be accurately predicted on basis of an available phosphate test alone, regardless of extracting solution employed. Soils which contained over 1.5 percent organic matter did not generally respond to phosphate, although "soil test available P<sub>2</sub>O<sub>5</sub>" levels were exceptionally low, and soils above pH 7.2 responded profitably to phosphate although soil test levels were high. If these factors organic matter and pH, at least are given due consideration, available P soil test may be evaluated with greater accuracy.

The use of an alkaline extracting solution, such as NaHCO<sub>3</sub>, for available P may eliminate the problem of alkaline soil pH, since it will result in extracting a lower quantity of P, but the weak acid extractant may be equally suitable if extraction time is reduced. With the Bray extracting solution - 0.1.N.HCl in 0.03 N ammonium fluoride - as adapted in Arkansas, rice will seldom respond profitably to P<sub>2</sub>O<sub>5</sub> addition unless soil test is below 10 ppm P<sub>2</sub>O<sub>5</sub>, and then only if organic matter is below 1.5 percent and pH below 7.2. The low-medium-high scale for evaluation of

soil test results has been found to be considerably lower (approximately one-half values) for rice than for dry-land crops on the same soil, because of the soil P release under submergence.

The amount of increase under submergence has been indicated to be proportional to the initial amount of easily soluble P in the dried soil if organic matter is constant and relatively low, but increasing amount of organic matter results in increasing proportions of P released under submergence. An additional simple measure of phosphorus absorption capacity, as used in Japan, could be of considerable value in predicting rate, kind and method of P application.

A guide for determination of fertilizer requirements from soil tests has been made available for Arkansas conditions, based upon correlations of soil tests from field fertilizer experiments on experiment stations and cultivators' fields over a number of years.

Since most countries are now conducting numerous fertilizer tests on cultivators' fields and experiment stations, it would be a simple matter to collect representative soil samples from the topsoil of the experimental sites just before the treatments are applied; if impossible, the control plots could be sampled at a later period, and the samples from numerous such sites air-dried immediately, then processed later when convenient. Although such sample results would not indicate the actual nutrient levels available under submergence, they would serve as suitable criteria for evaluating the initial fertility status of the soil and thus permit more critical and accurate interpretation of the field test results. For more fundamental research purposes, portions of the same samples might be incubated under submerged conditions, to determine the extent of extractable nutrient element changes.

In Malaya, the approach to soil fertility problems is somewhat different from that of the temperate climate countries. There is more interest in determining the variations in soil productivity from area to area than in ascertaining what there might be in particular fields. The soil scientists in Malaya are interested in determining what constitutes a good paddy soil. Their plan is to conduct soil surveys of paddy areas, delineate the soil boundaries and correlate soil analyses with crop cutting tests and results of fertilizer field trials. This type of work will lead to developing fertilizer recommendations on the soil type basis. Ultimately, it may be possible to extend these recommendations to individual fields.

In Malaya, and other likely regions, surveys of potential paddyland are difficult because of swampy jungles, etc., so traces may be cut and samples collected at quarter mile intervals on lines one mile apart. Pits are usually dug for profile sampling, but where waterlogging prevents this a 6" diameter auger is used to sample the 0-22.5 cm. and 22.5-45 cm. depths.

In open areas of established paddy lands, the grid system and pit sampling are readily adaptable, and use has been made of a tractor fitted with 18" diameter posthole auger for rapid borings to a three foot depth for mapping soil boundaries.

Routine analyses for fundamental research and soil survey work may include pH, mechanical analysis, moisture content, loss on ignition, carbon, total nitrogen, easily soluble phosphorus and potash; cation exchange capacity, conductivity, calcium, magnesium, sulphates and chlorides, exchangeable hydrogen, redox potential, mineralizable nitrogen, easily reducible manganese and iron, free iron oxides, silica-alumina ratio or type of clay mineral, and additional physical measurements of volume, weight, porosity and plasticity, may be desirable for more complete information, but are impractical for routine samples from numerous survey sample sites or cultivators' fields.

In Japan a soil survey and analysis manual was issued for the benefit of the field and laboratory workers who are at present engaged in establishing the fertilizer requirements of paddy fields. To this end, soils are first surveyed and classified and in this way the areas of similar soils are delineated. Experimental fields are then located near the centre of any particular soil unit and fertilizer trials are conducted for three years. Soil samples are taken at the time of soil survey from the survey pit; some are kept moist and others are dried. The consensus of opinion in Japan is that, at least for the present, it is not possible to predict from analysis the quantities of fertilizer to be applied to any particular field. Of course, physical and chemical analyses do provide valuable information. For example, phosphorus gives little response in Japan, but it is really effective on volcanic ash soils and this can be easily ascertained by analysis, as can the lack of potash and magnesium. But soil analysis is still regarded in Japan as only a supplementary measure and the final decision is always made only after the three year field trials are completed. The results of the trials are communicated to the agricultural agents in each village. The Japanese workers are of the opinion that at present the purpose of analysis is not to determine the amounts of fertilizer to be applied, but to search for unknown factors. Therefore, soil analysis should be as detailed as possible, in order to accumulate data for further progress.

At present the following four factors are considered to be of special significance in evaluating paddy soil productivity:

1. Good drainage conditions.
2. High clay content of a high silica-alumina ratio.
3. Presence of larger quantities of free iron and manganese.
4. Presence of medium quantity of mineralizable nitrogen.

Earlier workers in Japan concluded that, as nitrogen gives the greatest responses in Japan, the amount of mineralizable nitrogen should be determined to ascertain the productivity of the soil. Many an experiment proved that this is not the case. It was later found that if the soil contains much mineralizable nitrogen, this inevitably brings about much stronger reducing conditions during the process of nitrogen liberation. Such conditions lead to the formation of injurious reductive substances which entirely counteract the beneficial effects of the released nitrogen. Iron and manganese also exert a considerable influence, because in the oxidized state they tend to counteract the factors that help to bring about reducing conditions in submerged soils. Furthermore, reduced iron makes the hydrogen sulphide innocuous. As to the amount and quality of clay, it was found that soils of high productivity have a high silica-alumina ratio and abound in the montmorillonite type of clay. This soil is very easy to manage and, provided there is good drainage, will yield 80 bushels of paddy or more per acre regardless of slight variations in management. All soil factors are inter-related. For example, good drainage means the leaching of injurious reductive substances, but it also leads to leaching of bases. However, with montmorillonite type of clay the bases are not lost as readily.

In Japan, special analysis for other elements is carried out when particular circumstances warrant it.

In the last two years foliar diagnosis has been successfully used in French Tropical Africa for determining the fertilizer requirements of paddy. Numerous analyses have already demonstrated certain relationships between levels of soil fertility, yields and chemical balance in the leaves. It would appear in particular that nitrogen content of the latter increases with yield, reaching up to 3 percent of dry matter for yields of 6.5 tons per hectare on certain transplanted rice fields in Madagascar.

Work carried out in that territory has already demonstrated the differences in response to different fertilizers both as to yield and to the balance of elements in the paddy leaves. The varying results obtained according to the position of the leaves analysed, call for a standardisation of the sampling method. The foliar diagnosis technique is beginning to be used in the study of deficiencies and toxic effects of various micro elements, particularly manganese, in Middle Congo.

#### Suggestions for Future Work

The Working Party, having considered the various reports on soil sampling and analysis, and having taken into account all the various points made by the delegates, suggests that:

1. Countries conducting formal field fertilizer trials, either complex tests or simple tests on cultivators' fields or both, should make an effort to obtain soil samples at least representative of the topsoil 15 cm. from as many test sites as possible.

Analytical methods already adopted by the respective laboratories are suitable for the initial evaluation of soil test results compared to field fertilizer response, so long as the methods include at least pH, exchangeable H, total or easily oxidized organic matter, exchangeable or easily soluble P, K, Ca and Mg (with Na on soils where significant concentrations are likely to exist). Sulphur determinations are highly desirable for areas where "black root" is observed, and easily reducible manganese and iron, soluble aluminium, conductivity and phosphorus absorption capacity should be determined if at all possible. The results of such analysis should be included in reporting field experimental results. Methods for complete analysis have been made available by Japan, and additional rapid methods will be made available from Arkansas, as the characteristic of those commonly employed in successful programs in the United States of America.

2. In conjunction with the soil test data, foliar analyses on fertiliser test plots should be attempted in light of the French results, including at least measurements of N, P and K in panicular leaves.

3. Since information is still limited concerning concentration of soluble elements in soil solutions of submerged soils, fundamental chemical studies of submerged soils should be promoted, with particular emphasis on the possibilities of toxic concentration of reduced elements, such as iron, manganese and sulphides and interaction of such reduced substances upon each other as well as other essential elements within the rooting zone of problem soils where yields are frequently low, due to physiological conditions. Soil tests on submerged samples should especially include measurements of these factors, in addition to common fertility factors.

### Simple Fertilizer Tests on Cultivators' Fields

The FAO Consultant (H.N. Mukerjee) gave an account of the reasons which led him to start large-scale simple field tests on cultivators' fields in Bihar, India, since 1948. It was found that the advice given to the cultivators on the use of fertilizers, based on field experiments conducted at the Research Stations and soil chemical analysis, left much to be desired. The soils of the Research Stations had been brought to a different level of fertility, due to the residual effects of many years of manuring, introduction of irrigation facilities, better management, etc. For starting these tests on the fields of cultivators, Bihar was divided into 150 distinct soil zones, at each of which it was proposed to have one Field Assistant. The scheme passed through several stages of evolution and because of its great success it is now receiving the full support of the State. It started with only 50 field assistants working in certain restricted areas of the State, but under the second five year plan beginning from 1956 there will be 450 field assistants covering the whole State. The co-operative of the cultivators has grown from year to year and they are now only too eager to have the experiments conducted on their fields.

Under the second five year plan, not only fertilisers, but also research findings from all branches of agricultural science, such as new crop varieties, better cultivation practices, etc., will be rapidly and extensively tested under many different soil-climatic conditions. The name of the Scheme has also been changed from Manurial Tables Scheme to Field Experimental Service, thus implying an idea of service to the cultivators. About 16,000 experiments with different crops have been completed from 1948 to 1954, and further tests are being carried out this year.

The soil zones for the posting of Field Assistants were delineated from the results of a reconnaissance survey. The scheme for field experiments also included proposals for soil survey and mapping on the scale of 1" = 1 mile. As the soil survey portion of the scheme was only sanctioned in 1954, there was some difficulty in randomisation without accurate soil boundaries. For purposes of randomisation, therefore, either the boundaries of the administrative unit, or an area of six miles radius around the headquarters of the Field Assistant, is taken.

For each experiment, in addition to the normal agronomic records and observations, the soil profile is also examined and samples are collected for chemical analysis, so that a correlation between the soil tests and the response to different nutrients may be established. This enables the compilation of tables which prove very useful for giving fairly accurate advice to cultivators, in areas, where the chemical tests had been correlated with the nutrient responses.

A regular soil survey of the State was also started in 1954, and as the soil series and types are being differentiated from district to district,

arrangements are being made to pool the previous results and study them according to soil types and also to start new experiments at random, within the definitely defined soil boundaries.

As complete records of soil type, geological formation, irrigation etc. for each experiment are kept, the final results are statistically analysed, not only for the general responses for each area, sub-division, district or the whole State, but also for the interactions between different soils, geological formations and other agronomical factors, by pooling together the appropriate data from the general records.

The treatments in these experiments changed from time to time since 1948, depending on the nature of information, expected to prove of economic benefit to the farmers. In the first year, only 4 treatments were used, but as no difficulties were encountered in carrying out the experiments, number was increased to six in the second year. In the third year, seven treatments were tried, but this was found to be inconvenient and six treatments per experiment have now been accepted as a standard, with sub-plot sizes for each treatment of one-tenth of an acre. In hilly areas, where bigger plots are not available, the plot size is reduced to one-twentieth of an acre.

Each Field Assistant carries out six experiments at random on a particular crop, and as he handles five crops he has to carry out thirty experiments a year. The sites are selected at random. For this, three villages are selected at random and two plots in each of these villages are also selected at random, in the soil area. From 1948 to 1952, each experiment comprised six different treatments. In 1953, the possibilities of introducing a larger number of treatments, without increasing the number of experiments or plots per experiment were explored, with the help of the FAO Statisticians, Dr. Yates and Dr. Finney. A design was eventually worked out, which enabled one to obtain information on 15 treatments, without in any way increasing the field work. In the new design, which is now being used for the third year, information is being obtained on the effect of two levels each of N, P, and K, in different combinations and also on the effects of bone-meal as compared to superphosphate. The higher doses of fertilisers and the potash treatments are replicated less frequently than the others, as it is necessary to obtain more accurate information on the lower doses of N and P, which are of great economic importance to the cultivators.

The results from these experiments have so far helped to obtain information of considerable value.

1. The responses that may be obtained from the use of N, P, K, lime, compost, oil cake and bonemeal on different crops in different soil-climatic complexes of the State have been determined. This information is proving very useful in advising the farmers on the most economical doses of fertilisers.
2. Whereas in the past the soils of the Research Stations did not show much response to phosphates in general, tests on farmers'

fields have shown that response to P can generally be obtained on most soil types. It had been believed that Indian soils are mostly sufficient in P, but recent experiments on farmers' fields, in different States of India, have shown that P generally gives a fair response in several of the States of India.

3. Potash has not given much response on soils of the Research Farms in the past but the cultivators' plot experiments in Bihar, show that there are definite areas where K gives quite profitable yield increases. It is likely that if K were tried extensively on farmers' fields all over India definite areas of K response would be discovered.
4. The experimental results so far obtained also show very definitely the different zones in the State where very high responses may be obtained, as compared to others, through the use of the same quantities of fertilisers. This information may prove to be of great value for developing a State Fertiliser policy in an emergency, when a limited quantity of available fertilizers may have to be distributed in the high response areas, in order to maximize production at the minimum cost.
5. The experiments are also of great demonstration value. The cultivators are now paying the cost of all fertilisers and labour for experiments on their fields. This contrasts well with their attitude in the first year of the work, when they did not wish to co-operate. As a result of these tests, the cultivators are making increasing use of fertilisers, and many new fertiliser depots have had to be opened to meet the demand.

In Malaya, 108 of the 6-plot experiments were carried out on cultivators' fields in the 1954-55 season. All combinations of N, P, and  $P_2$  were tested with a basal dressing of K on the lighter soils. There was a good response to N and P in some areas, but results were of limited value in Kedah and Perlis, because 10 of the experiments were on unclassified soil and 10 others covered 7 different soil types. Soil survey is still in progress and is expected to be completed in two years' time, when the experiments would be distributed at random on specific soil types. In addition, about 1065 of 4-plot and 2-plot experiments and demonstrations have been carried out on cultivators' fields and good responses were demonstrated.

In Burma, fifty 6-plot experiments were carried out on the cultivators' fields in Pegu district. The pooled results from the whole district show that a dressing of 22.4 kgs. N and 33.6 kgs.  $P_2O_5$  per hectare gives the highest response, followed by a dressing of 44.8 kgs. N per hectare. It is, however, realised that it would be premature to draw definite conclusions from one year's results. It was found that the control plots of these fertiliser trials gave similar results to those from the neighbouring survey plots, and hence these can be used for the estimation of average unfertilised yields of different areas, instead of carrying out separate crop cutting surveys. It was, however, not clear why in some cases  $N_2P$  gave a lower yield than  $N_2$ , in this set of experiments.

In Thailand, a number of 4-plot and 2-plot demonstration trials were carried out with three levels of ammonium phosphate (16:20), and good results were obtained with 180 kgs. per hectare.

Progress Report on the Ad Hoc Working Party  
on Soil-Water-Plant Relationship

The Technical Secretary of the Working Party on Fertilizers reported that, in accordance with the recommendation made by the International Rice Commission at its Fourth Session in Tokyo in 1954, an ad hoc Working Group has been established to undertake detailed consideration of soil, water and plant relationships in the production of rice. The Director-General of FAO has invited the Governments of seven countries, in which substantial research work on the subject is under way, each to designate a member to the ad hoc Working Group. Five of these Governments accepted the invitation and designated the following members:

- |                |  |
|----------------|--|
| <u>India</u>   | - Mr. N. Parthasarathy, Director-General<br>Rice Institute, Cuttack  |
| <u>Italy</u>   | - Prof. A. Crocioni, Director, Istituto di<br>Agronomia generale e Coltivazioni erbacee,<br>Università di Torino, Torino                                     |
| <u>Japan</u>   | - Mr. Jisuke Takahashi, Chief, Plant Nutrition<br>Section, Chemical Division, National Institute<br>of Agricultural Sciences, Nishigahara, Kita-ku,<br>Tokyo |
| United Kingdom | - Mr. J.K. Coulter, Acting Senior Soil Chemist,<br>Federation of Malaya, Dept. of Agriculture,<br>Kuala Lumpur   |
| United States  | - Mr. L.C. Kapp, Rice Adviser, U.S. Operations<br>Mission to the Philippines, Manila   |

Mr. Aldert Molenaar, the Technical Secretary of the Working Group, is carrying out by correspondence the task assigned to the Group.

As a first step, the members were asked to collect available data and information on the subject within their respective countries, and to submit a report giving their analyses of the available data in the light of additional research needs, expressing their views on how the Working Group can most effectively complete its assigned task. Though none of the members has as yet submitted such a report, advance notices indicate that some of them will be doing so very soon, and it is expected that all members will submit their contributions before the end of 1955.

The Working Group fully expects to present a report to the International Rice Commission at its Fifth Session in 1956, setting forth its appraisal of the problems in the field of soil, water and plant relationships and of the kind of further research that will need to be undertaken for the satisfactory solution of these problems.

In 1939, rice cultivation in Western Japan suffered a great loss through drought. The Ministry of Agriculture and Forestry therefore established in 1941 a Prefectural Agricultural Experiment Station for the special task of developing methods of overcoming drought damage in rice cultivation. The Station was established in the Hofu Yamaguchi Prefecture, which is situated on the coast of the inland sea of Western Japan, where drought is most likely to occur.

A certain practice called "delayed irrigation" has been developed, meaning discontinuance of the water supply during the vegetative stage except for the first ten or so days when the rice plants are establishing themselves after transplanting, and again after flooding the fields at the beginning of the panicle formation. Such a procedure increases yields.

The results of experimental work up to date lead to the following conclusions:

- (1) Draining off all the water has an adverse effect on the vegetative growth of the paddy plant, thus the weight of the straw in "delayed irrigation" is always less than when the rice crop is grown on submerged soils.
- (2) When paddy suffering from water shortage is given ample water at the beginning of the panicle formation, the plants initiate a great many new roots. On the other hand, plants grown on submerged soils show signs of root decay at a time when water is most needed, as a result of being kept continually under reductive conditions.
- (3) Much research has already been done on the role of reductive substances in the decay of roots and, therefore, no further work is contemplated.
- (4) Chemical analysis shows that the suppression of vegetative growth leads to a greater amount of nutrients available for the reproductive stage.
- (5) The redox potential of paddy soils under "delayed irrigation" is always high, which is beneficial to the rice roots, especially at later stages of growth.
- (6) Experiments have shown that late transplanting cannot replace "delayed irrigation".
- (7) "Delayed irrigation" is most effective with moderate dressings of fertilizer.
- (8) It is believed that "delayed irrigation" is only applicable to South Japan. In the North, the growing period is too short and the delay of growth in the earlier stages cannot be overcome.

However, flooding throughout the whole growing period is not healthy for the rice roots. The best farmers, who can obtain as much as 9,000 kilogrammes of brown rice per hectare, follow a practice called "middle drying". By this is meant the discontinuance of the water supply in the "middle stage" of plant development.

- (9) There seems to be a possibility of obtaining greater yields with the consumption of much less water through the practices of "delayed irrigation" and "middle drying".

In French Upper Guinea along the Upper Niger there is an interesting demonstration of the relation of water to a series of rice varieties. The natural basins present a range of water depths which are correlated with the type and maturation period of the varieties grown. At the bottom of the basin occur the Indo-China floating varietal types maturing in seven and a half months. The milled grain yield of these types, as well as the percentage of red grains, increases markedly with decrease of water below 0.6 metres. Higher up the banks of the basins grow the Fossa varietal types resembling the "bulu", with a maturation period of five months. These varieties grow on moist soil subject to flooding. On the rim of the basins the upland rice varieties Bibim Balam are found, with a maturation period of 3-4 months.

PHYSIOLOGICAL DISEASES OF RICE

As convenor of the co-operative project on physiological diseases of paddy, Mr. A. Johnston (Malaya) reviewed progress during the past year and suggested lines for further investigations. He reported that work had been carried out in India, Pakistan and Malaya. In India, it was found that the disease was at a maximum when oxygen requirement was high and was associated with the presence of reduction products in the root zone. Application of phosphate and draining the fields reduced the severity of the disease. However, the effect of phosphate on the disease was not always consistent. In East Pakistan, it was noted that 'pansuk' disease was associated with stagnant water and partial recovery could be obtained by drainage and application of fertilizers. Both India and East Pakistan gave lists of varieties showing differing susceptibility to these diseases. In Malaya, work was in progress along the following lines: - growth in sand culture, pot experiments with soil from areas in which the disease had occurred, field fertilizer trials, varietal resistance, water stagnation, and nematodes.

Further discussion of the convenor's report brought to light additional pertinent information. Some past work in Burma has shown that application of phosphates had alleviated the diseases myit-po and amyit-po, even when applied after the diseases had appeared. Another physiological disease, "yellowing", was cured by the application of sulphur or sulphates.

In North Borneo, the orange type of leaf symptom occurred in rain-fed areas, and there is experimental evidence which suggests that the cause was Nephrotettix attack. Similar symptoms had also been observed in Malaya, but there were many cases in which the disease symptoms appeared when Nephrotettix was not present.

A survey of the literature indicates that the better growth of rice on submerged rather than on well drained soils is associated with the increase in the concentration of certain elements, especially iron and manganese. There is also evidence that under certain conditions these products of reduction can accumulate until they reach concentrations, which are toxic to the rice plant. In order to get a clearer picture of these relations, C.F. Ponnamperuma, of Ceylon, undertook the study of rice plants grown in pots in which a wide range of concentrations of iron and manganese were developed by subjecting the soil to different types of treatments:

- 1) 3 different pH values;
- 2) 3 different organic matter levels, and
- 3) different water levels.

Symptoms which seemed to be similar to those described in the literature as "mentek", "penyakit merah" or "browning disease" were produced by certain of the treatments. When the water drained from the pots was analyzed, the amount of growth of the rice and the intensity of the physiological symptoms were closely correlated with the concentration of the various products of reduction resulting from the various treatments. Ferrous and manganous ions were the predominating constituents in the drainage water, being present in concentrations of over 500 p.p.m. and 80 p.p.m. respectively at certain periods. The effect of the various treatments on the growth of the rice plants seemed to be associated primarily with the effect which they exerted upon the concentration of the products of reduction in spite of the fact that they differed widely in their nature and in their effect on other properties of the medium.

The proportion of the various products of reduction, many of which are probably toxic when present in sufficiently high concentrations, will vary with different soils and will probably produce variations in the foliar symptoms. Similar studies on other soils, under different climatic conditions and with different varieties of rice would appear to be justified.

These results offer an explanation of the effectiveness of many of the diverse practical remedies which have been proposed from time to time, such as: midseason drainage, ridging the soil around the rice plant about the level of the water, the better yields obtained when rice is grown in rotations involving upland crops, the benefits of drainage, etc. The greater prevalence of the "disease" in low spots which receive drainage water from higher adjacent areas can also be explained.

If the indications described above prove upon further study to be widely applicable, it should be relatively simple to develop:

- 1) diagnostic techniques applicable under field conditions - and
- 2) effective methods for remedying or even preventing these physiological diseases which are so widespread in the rice growing areas throughout the world.

In the United States of America, analyses of soils from submerged paddy fields in which physiological diseases occurred had been made. There was usually a high iron content but more consistent was the manganese/iron ratio, this always being less than 1/10. There was some evidence to show that this ratio was more important than the total amount of either element. Some French workers have found that, in areas of manganese toxicity, the amount of manganese in the leaves was also abnormally high.

In Indonesia, it has been found that the adventitious fibrous roots, which are affected by root rot, suffer from lack of oxygen and die, whereas the coarse roots have air spaces and do not suffer in this way. It would also appear that any agricultural practice which makes paddy soils more permeable to oxygenated water is beneficial in preventing physiological disease. In Indonesia, the good effect of phosphate is ascribed partly to the diminution of ferrous iron in the soil solution; partly to the stimulation of root formation; and partly to the stimulation of algae growth.

In the Tanjung Karang district of Selangor, Malaya, soon after land was put under paddy cultivation, there were large amounts of iron and organic matter in the soil but yields were very high. On the other hand, in old-established areas in Kedah, iron has been leached down to oxydation zone below the reducing zone, but 'penyakit merah' nevertheless sometimes occurs, suggesting that some factor other than excess iron may be involved. However, the important factor probably is not the total amount of iron in the soil but the amount in solution; this changes quickly, becoming high with water-logging.

In the United States of America, straighthead, another physiological disease, occurs on sandy soil under continuous flooding. The trouble can be partly cured by draining at the critical period, which probably corresponds with the time of panicle differentiation. A similar disease was reported from North Borneo, but it was considered unrelated to diseases of the 'penyakit merah' type.

Attention was drawn to the desirability of using leaf injection techniques for the investigation of physiological diseases, and it was mentioned that preliminary work on leaf injection and foliar spraying was being done in Malaya.

The joint meeting of the Working Parties on Rice Breeding and on Fertilizers recommended that the project on physiological diseases in paddy be continued as a co-operative one, and that interested governments continue their investigations, giving special attention to the following aspects:

- 1) the effect of reducing conditions in the soil;
- 2) the influence of the oxygen content of the water;
- 3) the effect of excess soluble iron in the soil;
- 4) the effect of application of heavy doses of phosphate;
- 5) repetition of the experiments reported by Dr. Ponnamperuma, et al;
- 6) investigations on soil microbiology;

- 7) growth of algae in wet rice fields;
- 8) leaf analyses;
- 9) the relation of Rhadopholus oryzae to physiological diseases.

#### Interaction Between Varieties and Fertilizers Response

In the absence of the delegate from Ceylon, the co-ordinator for this project, the summary report on investigations conducted in Malaya, Burma, U.S.A. and Indonesia was presented to the joint meeting of the Working Parties by the Technical Secretary Rice Breeding. Information relating to India received subsequently was presented at the meeting by the delegate from India.

Malaya. In Malaya, 11 indigenous varieties were tested at two fertilizer levels in six centers. At all centers except one, the response to fertilizers was striking, and at two centers, varieties responded differentially to fertilizers. At one center, two varieties showed a conspicuous response while another did not benefit from fertilizer applications. Three japonicas from Taiwan, tested in 1951, showed marked response to fertilizers, but the interaction between varieties and fertilizers, was not significant. In the second series of trials, a pure line selection was tested against local varieties on manured and unmanured plots on 25 small holdings. The effects of manuring on all varieties were significant, but the varieties showed no differential response to manuring.

Burma. A trial in Hmawbi which commenced in 1953 and continued for two seasons included 5 varieties and 3 fertilizer levels with N and P. While the main effects were significant, the variety-fertilizer interaction was not. A trial in Mandalay with 20 varieties at three fertilizer levels of N and P also showed that the main effects were significant, but the varieties did not interact significantly with fertilizers.

United States of America. At Stuttgart, Arkansas, 3 varieties were tested at three levels of N. Varieties and fertilizers showed significant effects as well as differential response of varieties to fertilizers.

At Beaumont, Texas, the performance of two early maturing varieties was compared at four levels of N, two levels of P and two levels of K. Not only were main effects significant, but the variety-fertilizer interaction assumed significance at the 1% point. While one variety

had a striking fertilizer response, the fertilizer application actually depressed the grain yield in the other. Although the experiments did not clearly indicate the nutrient elements to which the varieties responded differentially, other trials conducted on Beaumont clays suggest that the main response is to nitrogen.

Indonesia. A range of 20 varieties including early and late forms of indicas and bulus were compared at two levels of N and two levels of P. The effect of N was significant at 1% point, but P produced no yield increase. There were strikingly significant differences between and within groups of varieties, but the variety-fertilizer interaction did not reach significance. The analyses appeared to show that the replications differed markedly in soil fertility.

Passing over the results from the various countries under review, one notes that U.S.A. and Malaya report striking instances of differential response of varieties to fertilizers.

The experiments confirm the view expressed in the co-ordinator's previous report that marked differences in fertilizer response exist within the indica group.

Considerable difficulty is experienced in interpreting the results of experiments in which effects of N and P are not separable. The need for ensuring that levels N and P are combined factorially, so that separate assessments of the individual effects of these elements become possible, cannot be too strongly stressed. For various reasons, investigators in most countries have manifested greater interest in the varietal response to nitrogen, and the term 'fertilizer response' has often been used synonymously with 'nitrogen response'. Since the initiation of this co-ordinated project, no country has reported any instance of a differential response of varieties specifically to P. Recorded cases of varietal response to N, on the other hand, have not been uncommon even in the indica group. While the recent investigations of the Japanese workers have thrown considerable light on the nature of varietal response to N, there is no comparable information on the nature of the response to P.

Many soils show a marked interaction between nitrogen and phosphate; there may be no response to nitrogen unless the phosphorus level is adequate. It is, accordingly, necessary, even in trials designed to evaluate variety-nitrogen interaction, to incorporate a satisfactory basal dressing of phosphorus and even of potash as well. Limiting factors should not be permitted to interfere with the expression of nitrogen response.

Low-response varieties prefer nitrogen applications as late as is practicable. Indeed an interaction between varieties and the time of nitrogen application has been demonstrated in the U.S.A. The investigations in Malaya reported are also suggestive. The fact that early applications

of nitrogen accentuate differences in fertilizer response should be noted in the design of experiments. Preferably, time of nitrogen application should be combined factorially with varieties and nitrogen levels. If the inclusion of times of nitrogen application as a treatment is not possible, early application of nitrogen should be insisted on.

Investigations at Cuttack, India, consisted of 65 varieties grouped into three maturity classes and tested under three levels of N and P. The variety-fertilizer interaction was evident only in the late maturity class, while the yield in the early and medium maturity classes was depressed due to premature lodging.

A report of a trial in Thailand with six varieties and three levels of N and P at three centers was presented to the meeting. The data would seem to indicate variety-fertilizer interaction.

In a trial in which blocks differ markedly in fertility, the inclusion of varieties showing differential response to fertilizers would inflate the combination of the within-block variance appropriate to error, and may prevent the demonstration of significant variety-fertilizer interaction. It is suggested that in variety trials, blocks possessing, as far as possible, the same average fertility should be used. Moreover, the use of split-plot designs with fertilizer treatments occupying the main plots, and varieties the sub-plots, may be profitably employed. Such designs, although possessing fewer degrees of freedom for error than the simple randomized block designs with the same number of replications, appear to provide greater precision in the testing of variety-fertilizer interactions.

In the discussion following the presentation of reports on this subject, field plot technique came up for consideration and the FAO Statistician (S. Mazumdar) explained that there were factorial designs in which the number of plots necessary for an experiment may be even smaller than the total number of treatment combinations. It would be possible to study numerous factors at various levels with a factorial approach. Many experimenters have found difficulty in combining varieties of different maturity periods. There may be statistical hazards in combining varieties of widely differing maturity periods and growth habits in a single experiment. For experiments of the kind under discussion, the split plot design should be more useful, although Mr. Mazumdar was not sure about the advantage of dealing with fertilizer treatments in the main plots and varieties in sub plots. If there were differential reaction to application of fertilizers by different groups of varieties, it should be possible to derive both inter-group and within-group interactions. Mr. Mazumdar said that it might be possible to extend the analysis of even the present data to bring out additional information. He drew attention to the necessity for the services of statisticians at experimental stations, particularly in the earlier stages of designing layouts. Although there might be differences between the suggestions of

the Statistician and the practicability of recommended layouts under field conditions, these could be overcome by considering all points before the experiment was actually started.

An opinion was expressed that emphasis should be changed from nitrogen to phosphorus because of the economic and agronomic advantages of providing the phosphate to the plant at as early a stage in the growth as possible. In this connection the study of interaction between varieties and nursery manuring was recommended. Quantity of phosphorus to be used will depend on the nature of the soil concerned. Questions on time of fertilizer application and their effect on the strength of straw were also raised. Further discussions were held on whether the present trials should be continued on the existing lines or be redesigned to obtain information on: time of fertilizer application, variety-phosphate interaction, calculation of the regression function to secure a correct estimate of the fertilizer response unaffected by other variables etc. On the last point the Statistician was of the opinion that such investigations might involve different trials. After further discussion the Working Parties recommended that the co-operative investigation on the interaction of fertilizer response with varieties be continued.

PAPERS PRESENTED TO THE MEETING

The Working Party had before it a considerable number of papers prepared by individuals, institutes, or departments in Member Countries and by FAO, relating to various subjects currently under consideration by the Working Party. These papers were presented as mimeographed documents specifically for use in the Meeting. Titles and authors are listed below, arranged by countries of origin, to provide a permanent record of the papers presented, and also as an acknowledgment of the important and detailed contributions made to the deliberations of the Working Party.

Australia

Rice rotations in New South Wales, by W. Poggendorff.

Burma

Report on the Fertilizer Experiments on Paddy laid out in the Cultivators' Fields in Pegu District.

The Analyses of the Results of 25 Nitrogen-Phosphate Experiments in Pegu District of Lower Burma, by C.T. de Wit and U Khin Win.

Diseases of Paddy in Burma due to Physiological Causes.

Ceylon

Report of the Co-ordinator for the investigation of Interactions between varieties and fertilizers with particular Reference to N and P, by M.F. Chandraratna.

Egypt

Paddy yield as Affected by Crop Rotation, by M.T. Eid.

France

Fertilisation du Riz sur les hauts plateaux de Madagascar, par P. Roche, J. Velly et B. Jolliet.

Essai de chaulage sur riz a Madagascar, par P. Roche, J. Velly et B. Jolliet.

Essai d'Interprétation des analyses foliaires du riz dans la région du Lac Alaotra, par P. Roche, J. Velly et B. Jolliet.

India

Effect of Crop Rotations on the Growth and Yield of Rice in India, by M.V. Vachhani.

Response of Paddy to Fertilizers in India, by B.N. Lal.

Indonesia

Investigation on the time application of ammonium sulphate, by H. Siregar.

Notes on Crop Rotation in Sawah Cultivation in Indonesia, by Dahro.

Italy

Effects of rotation on the growth and production of rice in Italian paddy fields - use of fertilizer and green manures, by Jean Sampietro.

Japan

Soil Survey and Analysis.

Effect of Silica upon Rice, by K. Imaizumi.

Soil, Water, Plant Relationship, by Jisuke Takahashi.

Korea

Efficiency of various nitrogenous carriers on Korean paddy soils.

Philippines

Rice fertilization in the Philippines, by Eulalio P. Baltazar.

Response of rice to fertilization in four Southern Provinces of Luzon, by N.L. Galvez, T.C. Cruz, M.E. Raymundo, J.G. Davide and P.A. Santos.

Thailand

Experiment Type A and A-1 by Sarot Montrakun.

Experiment Type A-2 by Sarot Montrakun.

Experiment Type A-3 Application of ammonium sulphate and rock phosphate on rice, by Sarot Montrakun.

Type B Experiment - The application of nitrogen, phosphorus, potassium and lime on rice, by Sarot Montrakun.

Experiment Type D - Spacings and fertility levels, by Sarot Montrakun.

Experiment Type Time N - Time of nitrogen application, by Sarot Montrakun.

Experiment Type C - Interaction between varieties and fertilizers, by Sarot Montrakun.

### United Kingdom

The effect of crop rotation on growth and yield of paddy, by E.F. Allen.

Double cropping of wet paddy Province Wellesley, by E.F. Allen and J.R. Milburn.

6-Plot fertilizer trials on smallholders' land, by E.F. Allen.

N.P.K. Factorial trial on wet paddy in Malaya, by E.F. Allen and R. Henderson.

Wet paddy manurial experiments on peat soils in Malaya, by E.F. Allen and J.K. Coulter.

Sampling and analysis of paddy soil, by G.W. Arnott.

Soil survey of jungle swamps for paddy cultivation, by J.K. Coulter.

Soil survey of established paddy growing areas of the Kedah-Perlis Coastal Plain, by A.R. McWalter.

Review of investigations into physiological diseases of rice, by A. Johnston.

Studies on Penyakit Merah of the paddy plant, by J.K. Coulter and R.G. Lockhard.

Foliar symptoms of deficiencies of the major elements in rice, by R.G. Lockhard.

Research on Penyakit Merah in Malaya, by R.G. Lockhard.

### United States

The effect of crop rotation on the growth and yield of rice in the United States, by C. Roy Adair.

### Food and Agriculture Organization

Outline of Lectures, Second International Training Center on Soil Fertility in Relation to Rice Growing, FAO in co-operation with the Government of India.

Review. The Effect of Crop Rotation on Growth and Yield of Paddy, by G.A.W. Van de Goor (FAO Consultant).

Designs of rotation experiments in Paddy Cultivation, by S. Mazumdar.

Response of paddy to fertilizer.

Sampling and analysis of paddy soils, by R.L. Beacher (FAO Consultant).

Guide for rice fertilizer, recommendations in Arkansas, by R.L. Beacher (FAO Consultant).

Progress report on the ad hoc Working Party on Soil-Water-Plant relationship.  
FAO/56/1/208

TIME AND PLACE OF THE NEXT MEETING

The Working Party on Fertilizers decided to recommend the acceptance of the generous offer of the Government of India and to hold its sixth meeting together with the seventh meeting of the Working Party on Rice Breeding in India in 1956. These meetings will commence just prior to the Fifth Session of the International Rice Commission but the exact time and place will be announced later.





